without incision of the chest wall to reduce burden on the patient.

Claims

1. An ultra miniature integrated cardiac pacemaker requiring no chest incision, and can be implanted in the heart by attaching to the tip of a catheter and extracting the catheter after implanting, comprising:
   - a control unit that outputs control signals;
   - a heart stimulating means that responds to the said control signal and electrically stimulates the heart tissue;
   - an electrocardiographic information detecting means that detects electrocardiographic information and outputs to the said control unit;
   - a power unit that supplies the driving power;
   - wherein the said control unit outputs control signal based on electrocardiographic information;
   - wherein the said power unit is a biological fuel cell that extracts electrons from oxidative reactions of biological fuels;
     - wherein the said biological fuel cell is composed of an anode electrode and a cathode electrode;
     - while the said anode electrode is coated with immobilized oxidative enzymes for biological fuels and mediators;
     - and is characterized by using blood and/or body fluid as electrolyte solution and utilizing biological fuels and oxygen in blood and/or body fluid.

2. An ultra miniature integrated cardiac pacemaker requiring no chest incision, and can be implanted in the heart by attaching to the tip of a catheter and extracting the catheter after implanting, comprising:
   - a control unit that outputs control signals;
   - a heart stimulating means that responds to the said control signal and electrically stimulates the heart tissue;
   - an electrocardiographic information detecting means that detects electrocardiographic information and outputs to the said control unit;
   - a transmitting means that modulates the electrocardiographic information and control signal to be sent outside;
   - a power unit that supplies the driving power;
   - wherein the said control unit outputs control signals based on electrocardiographic information
   - wherein the said power unit is a biological fuel cell that extracts electrons from oxidative reactions of biological fuels;
     - wherein the said biological fuel cell is composed of an anode electrode and a cathode electrode;
     - while the said anode electrode is coated with immobilized oxidative enzymes for biological fuels and mediators;
     - and is characterized by using blood and/or body fluid as electrolyte solution and utilizing biological fuels and oxygen in blood and/or body fluid.

3. An ultra miniature integrated cardiac pacemaker requiring no chest incision, and can be implanted into the heart by attaching to the tip of a catheter and extracting the catheter after implantation, comprising:
   - a control unit that outputs control signals;
   - a heart stimulating means that responds to the said control signal and electrically stimulates the heart tissue;
   - an electrocardiographic information detecting means that detects electrocardiographic information and outputs to the said control unit;
   - a receiving means that demodulates information transmitted from the exterior;
   - a power unit that supplies the driving power;
   - and designed such that information sent from outside is input into said control unit
   - wherein the said control unit outputs control signals based on information sent from outside and/or electrocardiographic information;
   - wherein the said power unit is a biological fuel cell that extracts electrons from oxidative reactions of biological fuels;
     - wherein the said biological fuel cell is composed of an anode electrode and a cathode electrode;
     - while the said anode electrode is coated with immobilized oxidative enzymes for biological fuels and mediators;
     - and is characterized by using blood and/or body fluid as electrolyte solution and utilizing biological

fuels and oxygen in blood and/or body fluid.

4. An ultra miniature integrated cardiac pacemaker requiring no chest incision, and can be implanted into the heart by attaching to the tip of a catheter and extracting the catheter after implantation, comprising:
   - a control unit that outputs control signals;
   - a heart stimulating means that responds to the said control signal and electrically stimulates the heart tissue;
   - an electrocardiographic information detecting means that detects electrocardiographic information and outputs to the said control unit;
   - a transmitting means that modulates the electrocardiographic information and control signal to be sent outside;
   - a receiving means that demodulates information transmitted from outside;
   - a power unit that supplies the driving power;
   - and designed such that information sent from outside is input into said control unit;
   - wherein said control unit outputs control signals based on information sent from outside and/or electrocardiographic information;
   - wherein the said power unit is a biological fuel cell that extracts electrons from oxidative reactions of biological fuels;
     - wherein the said biological fuel cell is composed of an anode electrode and a cathode electrode;
     - while the said anode electrode is coated with immobilized oxidative enzymes for biological fuels and mediators;
     - and is characterized by using blood and/or body fluid as electrolyte solution and utilizing biological fuels and oxygen in blood and/or body fluid.

5. A cardiac pacing system comprising an ultra miniature integrated cardiac pacemaker placed in the atrial myocardium,
   - wherein the said ultra miniature integrated cardiac pacemaker comprises:
     - a control unit that outputs control signal;
     - a power unit that supplies driving power;
     - a heart stimulating means that responds to the said control signals and electrically stimulates the atrial myocardium;
     - an electrocardiographic information detecting means that detects electrocardiographic information including at least intracardiac P wave information,
     - wherein the said power unit is a biological fuel cell that extracts electrons from oxidative reactions of biological fuels,
       - wherein the said biological fuel cell is composed of an anode electrode and a cathode electrode;
       - while the said anode electrode is coated with immobilized oxidative enzymes for biological fuels and mediators;
       - and is characterized by using blood and/or body fluid as electrolyte solution and utilizing biological fuels and oxygen in blood and/or body fluid,
     - wherein the said control unit comprises:
       - a stimulation timing determining means that decides the timing of stimulation to generate control signals;
       - a stimulation timing changing means that changes the timing of stimulation to generate control signals,
       - and is characterized by changing timing of stimulation to generate control signal, if intracardiac P wave information is detected within a preset time interval.

6. A distributed cardiac pacing system comprising an electrocardiographic information detecting device placed in the atrial myocardium and an ultra miniature integrated cardiac pacemaker placed in the ventricular myocardium,
   - wherein the said electrocardiographic information detecting device comprises:
     - an electrocardiographic information detecting means that detects electrocardiographic information including at least intracardiac P wave information;
     - a transmitting means that modulates detected electrocardiographic information and sends information to

said ultra miniature integrated cardiac pacemaker;
- a power unit that supplies driving power;
- wherein the said power unit is a biological fuel cell that extracts electrons from oxidative reactions of biological fuels,
  - wherein the said biological fuel cell is composed of an anode electrode and a cathode electrode;
  - while the said anode electrode is coated with immobilized oxidative enzymes for biological fuels and mediators;
  - and is characterized by using blood and/or body fluid as electrolyte solution and utilizing biological fuels and oxygen in blood and/or body fluid,
- wherein the said ultra miniature integrated cardiac pacemaker comprises:
  - a receiving means that receives and demodulates electrocardiographic information sent from said electrocardiographic information detection device;
  - a control unit that outputs control signal;
  - a power unit that supplies the driving current;
  - a heart stimulating means that responds to the said control signal and electrically stimulates the ventricular myocardium,
  - wherein the said power unit is a biological fuel cell that extracts electrons from oxidative reactions of biological fuels,
    - wherein the said biological fuel cell is composed of an anode electrode and a cathode electrode;
    - while the said anode electrode is coated with immobilized oxidative enzymes for biological fuels and mediators;
    - and is characterized by using blood and/or body fluid as electrolyte solution and utilizing biological fuels and oxygen in blood and/or body fluid,
  - wherein the said control unit comprises:
    - a stimulation timing determining means that decides the timing of stimulation to generate control signals;
    - a stimulation timing changing means that changes the timing of stimulation to generate control signals;
    - and is characterized by generating control signals when intracardiac QRS complex information is not detected within a given time after detection of intracardiac P wave information, and suppressing the control signals when QRS complex information is detected within a given time after detection of intracardiac P wave information.

7. A distributed cardiac pacing system comprising a first ultra miniature integrated cardiac pacemaker placed in the atrial myocardium and a second ultra miniature integrated cardiac pacemaker placed in the ventricular myocardium,
- wherein the said first ultra miniature integrated cardiac pacemaker comprises:
  - a control unit that outputs control signal;
  - a power unit that supplies driving power;
  - a heart stimulating means that responds to the said control signal and electrically stimulates atrial myocardium;
  - an electrocardiographic information detecting means that detects electrocardiographic information including at least intracardiac P wave information;
  - a transmitting means that modulates the electrocardiographic information and sends the information to the said second ultra miniature integrated cardiac pacemaker;
  - a receiving means that receives and demodulates the electrocardiographic information sent from the said second ultra miniature integrated cardiac pacemaker,
  - wherein the said power unit is a biological fuel cell that extracts electrons from oxidative reactions of biological fuels,
    - wherein the said biological fuel cell is composed of an anode electrode and a cathode electrode;
    - while the said anode electrode is coated with immobilized oxidative enzymes for biological fuels and mediators;
    - and is characterized by using blood and/or body fluid as electrolyte solution and utilizing biological fuels and oxygen in blood and/or body fluid,

- wherein electrocardiographic information sent from the said second ultra miniature integrated cardiac pacemaker is input into said the control unit; and the said control unit has a stimulation timing determining means that decides the timing of stimulation to generate control signals, and a stimulation timing changing means that changes the timing of stimulation to generate control signals,

- wherein the said second ultra miniature integrated cardiac pacemaker comprises:
  - a control unit that outputs control signals;
  - a power unit that supplies the driving current;
  - a heart stimulating means that responds to said control signal and electrically stimulates ventricular myocardium;
  - an electrocardiographic information detecting means that detects electrocardiographic information including at least intracardiac QRS complex information;
  - a transmitting means that modulates electrocardiographic information and sends to the said first ultra miniature integrated cardiac pacemaker;
  - a receiving means that receives and demodulates electrocardiographic information sent by the said first ultra miniature integrated cardiac pacemaker,
  - wherein the said power unit is a biological fuel cell that extracts electrons from oxidative reactions of biological fuels,
    - wherein the said biological fuel cell is composed of an anode electrode and a cathode electrode;
    - while the said anode electrode is coated with immobilized oxidative enzymes for biological fuels and mediators;
    - and is characterized by using blood and/or body fluid as electrolyte solution and utilizing biological fuels and oxygen in blood and/or body fluid,
  - wherein electrocardiographic information sent from the said first ultra miniature integrated cardiac pacemaker is input into the said control unit; and the said control unit is equipped with a stimulation timing determining means that decides timing of stimulation to generate control signals, and a stimulation timing changing means that changes timing of stimulation to generate control signal.
- wherein control unit of the said first ultra miniature integrated cardiac pacemaker generates control signal when intracardiac P wave information is not detected within a given time, and suppresses generation of control signal when intracardiac P wave information is detected within a given time.
- wherein control unit of the the said second ultra miniature integrated cardiac pacemaker generates control signals when intracardiac QRS complex information is not detected within a given time after detection of intracardiac P wave information, and suppresses generation of control signals when intracardiac QRS complex information is detected within a given time after detection of intracardiac P wave information.
- wherein the system is characterized by: if the said second ultra miniature integrated cardiac pacemaker detects intracardiac QRS complex information due to spontaneous ventricular contraction, control unit of the said first ultra miniature integrated cardiac pacemaker suppresses detection of intracardiac P wave information for a given time interval.

8. A distributed cardiac pacing system comprising an electrocardiographic information detection device placed in atrial myocardium and multiple ultra miniature integrated cardiac pacemakers placed in ventricular myocardium,
- wherein the said electrocardiographic information detection device comprises:
  - an electrocardiographic information detecting means that detects electrocardiographic information including at least intracardiac P wave information;
  - a transmitting means that modulates detected electrocardiographic information and sends to the said ultra miniature integrated cardiac pacemakers;
  - a power unit that supplies the driving current,
  - wherein the said power unit is a biological fuel cell that extracts electrons from oxidative reactions of biological fuels,
    - wherein the said biological fuel cell is composed of an anode electrode and a cathode electrode;
    - while the said anode electrode is coated with immobilized oxidative enzymes for biological fuels and mediators;
    - and is characterized by using blood and/or body fluid as electrolyte solution and utilizing biological fuels and oxygen in blood and/or body fluid,

- wherein the said ultra miniature integrated cardiac pacemaker comprises:
  - a control unit that outputs control signals;
  - a power unit that supplies the driving power;
  - a heart stimulating means that responds to the the said control signals and electrically stimulates the ventricular myocardium;
  - an electrocardiographic information detecting means that detects electrocardiographic information including at least intracardiac QRS complex information;
  - a transmitting means that modulates electrocardiographic information and sends to other ultra miniature cardiac pacemakers;
  - a receiving means that receives and demodulates electrocardiographic information sent from other ultra miniature integrated cardiac pacemakers
  - wherein the said power unit is a biological fuel cell that extracts electrons from oxidative reactions of biological fuels,
    - wherein the said biological fuel cell is composed of an anode electrode and a cathode electrode;
    - while the said anode electrode is coated with immobilized oxidative enzymes for biological fuels and mediators;
    - and is characterized by using blood and/or body fluid as electrolyte solution and utilizing biological fuels and oxygen in blood and/or body fluid,
  - wherein electrocardiographic information sent from other ultra miniature integrated cardiac pacemakers is input into the said control unit; and the said control unit is equipped with a stimulation timing determining means that decides the timing of stimulation to generate control signals, and a stimulation timing changing means that changes the timing of stimulation to generate control signals,
- wherein the system is characterized by: if the said individual ultra miniature integrated cardiac pacemakers do not detect intracardiac QRS complex information within respective preset times after detection of intracardiac P wave information, control units of the said ultra miniature integrated cardiac pacemakers generate control signals; whereas if QRS complex information is detected within given times after detection of intracardiac P wave information, control units generate control signals synchronous to the earliest timing at which intracardiac QRS complex information is first detected.

9. A distributed cardiac pacing system comprising a first ultra miniature integrated cardiac pacemaker placed in the atrial myocardium and multiple second ultra miniature integrated cardiac pacemakers placed in the ventricular myocardium.
- wherein the said first ultra miniature integrated cardiac pacemaker comprises:
  - a control unit that outputs control signals;
  - a power unit that supplies the driving power;
  - a heart stimulating means that responds to the said control signals and electrically stimulates atrial myocardium;
  - an electrocardiographic information detecting means that detects electrocardiographic information including at least intracardiac P wave information;
  - a transmitting means that modulates electrocardiographic information and sends to the said multiple second ultra miniature cardiac pacemakers;
  - a receiving means that receives and demodulates electrocardiographic information sent by the said multiple second ultra miniature integrated cardiac pacemakers,
  - wherein the said power unit is a biological fuel cell that extracts electrons from oxidative reactions of biological fuels,
    - wherein the said biological fuel cell is composed of an anode electrode and a cathode electrode;
    - while the said anode electrode is coated with immobilized oxidative enzymes for biological fuels and mediators;
    - and is characterized by using blood and/or body fluid as electrolyte solution and utilizing biological fuels and oxygen in blood and/or body fluid,
  - wherein electrocardiographic information sent from the said multiple second ultra miniature integrated cardiac pacemakers are input into the said control unit; and the said control unit is equipped with a stimulation timing determining means that decides the timing of stimulation to generate control signals, and a stimulation timing changing means that changes the timing of stimulation to generate control

signals.

- wherein the said multiple second ultra miniature integrated cardiac pacemakers comprise:
  - a control unit that outputs control signals;
  - a power unit that supplies the driving power;
  - a heart stimulating means that responds to the said control signal and electrically stimulates the ventricular myocardium,
  - an electrocardiographic information detecting means that detects electrocardiographic information including at least intracardiac QRS complex information;
  - a transmitting means that modulates electrocardiographic information and sends to the said first and second ultra miniature integrated cardiac pacemakers;
  - a receiving means that receives and demodulates electrocardiographic information sent from the said first and other second ultra miniature integrated cardiac pacemakers,
  - wherein the said power unit is a biological fuel cell that extracts electrons from oxidative reactions of biological fuels,
    - wherein the said biological fuel cell is composed of an anode electrode and a cathode electrode;
    - while the said anode electrode is coated with immobilized oxidative enzymes for biological fuels and mediators;
    - and is characterized by using blood and/or body fluid as electrolyte solution and utilizing biological fuels and oxygen in blood and/or body fluid,
  - wherein electrocardiographic information sent from the said first and other second ultra miniature integrated cardiac pacemakers is input into the said control unit; and the said control unit is equipped with a stimulation timing determining means that decides timing of stimulation to generate control signals, and a stimulation timing changing means that changes timing of stimulation to generate control signals,
- wherein control unit of the said first ultra miniature integrated cardiac pacemaker generates control signal if intracardiac P wave information is not detected within a given time, and suppresses generation of control signal if intracardiac P wave information is detected within a given time,
- wherein control units of the said multiple second ultra miniature integrated cardiac pacemakers generate control signals if intracardiac QRS complex information is not detected by individual ultra miniature integrated cardiac pacemakers within the respectively preset times after detection of intracardiac P wave information; whereas if intracardiac QRS complex information is detected within given times after detection of intracardiac P wave information, control units generate control signals synchronous to the earliest timing at which intracardiac QRS complex information is detected.
- wherein the system is characterized by: if one of the said multiple second ultra miniature integrated cardiac pacemakers detects intracardiac QRS complexes due to spontaneous ventricular contraction, control unit of the said first ultra miniature integrated cardiac pacemaker suppresses detection of intracardiac P wave information for a given time interval.